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DESIGN OF AN INSTRUCTIONAL STRATEGY TO TEACH VISUALIZATION IN AN ADVECTION CONTEXT IN INTELLIGENT COMPUTER-ASSISTED INSTRUCTION

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PREFACE

The mission of the Intelligent Systems Branch of the Training Systems Division of the Air Force Human Resources Laboratory (AFHRL/IDI) is to design, develop, and evaluate the application of artificial intelligence (AI) technologies to computer-assisted training systems. The current effort was undertaken as part of IDI's research on intelligent tutoring systems (ITS), ITS development tools, and intelligent computer-assisted training testbeds. The work was accomplished under workunit 1121-09-70, the development of a knowledge-based intelligent tutoring system.

SUMMARY

This document contains the domain-independent instructional strategy to teach a cognitive strategy and its associated instantiation for a visualization strategy in the domain of weather. Further, rules and implementation suggestions are provided to support a design for an implementation of an intelligent computer-assisted instruction (CAI) program to teach approximately an hour of the domain of advection. Advection is the process that transports atmospheric properties (e.g., temperatures) by the wind. Advection is usually used to describe large scale horizontal movement in the atmosphere. The vertical motions of the atmosphere can be inferred by finding the proper advection patterns. Ultimately, it is the vertical motions in the atmosphere that produce the changes in weather.

Introduction

This third technical deliverable is our final report for the instructional design aspects of our subcontract. The report provides an iterative update for our prior technical deliverables (e.g., O'Neil & Jacoby, 1990). We have chosen to implement an iterative process to accomplish our milestones for Task 3 as specified in the Expert-EASE/ADI proposal (see Appendix A, which is page 34 of the Expert-EASE Proposal). This third technical deliverable augments the second technical deliverable in the following manner: (a) almost all drawings are presented in computer-readable form; (b) general rules for teaching visualization are provided; (c) remediation rules for teaching visualization are provided; (d) all multiple choice instantiations have four options; (e) all references are provided; (f) suggestions for adding color and motion are provided. This third deliverable uses, where appropriate, the same text of our second deliverable.

This document contains the domain-independent instructional strategy to teach a cognitive strategy and its associated instantiation for a visualization strategy in the domain of weather. Further, rules and implementation suggestions are provided to support a design for an implementation of an intelligent computer-assisted instruction (ICAI) program to teach approximately an hour of the domain of advection. Advection is the process that transports atmospheric properties (e.g., temperature) by the wind. Advection is usually used to describe large scale *horizontal* movement in the atmosphere. The vertical motions of the atmosphere can be inferred by finding the proper advection patterns. Ultimately, it is the *vertical motions* in the atmosphere that produce the changes in weather.

The objective for this one-hour intelligent computer-assisted instruction program would be:

> Given thickness and vorticity charts (i.e., a two-dimensional representation) and particular geographical locations, the student will adopt a visualization strategy (i.e., a three-dimensional representation) to determine the expected

vertical motion of air at each geographical location. The student will use learning aids with 80% accuracy in 15 minutes.

The basis for the instructional strategy and rule set was in part represented by our prior work in the area of domain-independent and domain-specific instructional strategies for knowledge bases (O'Neil, Slawson & Baker, 1987). It was supplemented by further analytical work in the design of domain-independent problem solving instructional strategies (O'Neil, Slawson, & Baker, in press). Finally, we conducted knowledge elicitation of Air Force weather experts for two days at Chanute AFB. We have also involved our chief instructional strategy consultant (i.e., Dr. Robert Gagné); Dr. Gagné's role is to review our technical deliverables. Dr. Gange's feedback was implemented where appropriate.

The document is organized in six sections. the first, Introduction, was included to provide background and context. The second, Domain-Independent Instructional Strategy, contains the domain-independent instructional strategy. The third section, Implementation Issues and Wrap-Around Design, includes implementation issues and the wrap-around design for the instructional materials. The fourth, Instructional Strategy Rule Set, provides an overview of the instructional strategy rule set and instructional instantiations to implement the design structure. The fifth section provides domain-independent strategy rules and the final section, Concluding Remarks, provides a summary.

Domain-Independent Instructional Strategy

A particularly knotty problem associated with developing the framework for domain-independent instructional strategies has been determining the boundaries of concepts such as "domain"and "independent." We believed that a domain-independent set of instructional knowledge would be critical to obtaining any leverage of effort from a knowledge-based approach.

Our solution to this issue is based on two key assumptions: (a) it is mandatory for instructional practices to specify for the designer the outcome or objective of the learning (e.g., cognitive strategy); and (b) various outcomes (e.g., cognitive stratetgies) have specific learning conditions, i.e., instructional strategies. The second assumption was adopted from the framework of Gagné, Briggs and Wager (1988) and Merrill (1983). These learning conditions are dependent on outcome (e.g., cognitive strategy), but are independent of domain (e.g., weather). Thus, these learning conditions or strategies are assumed to be independent of subject matter or application area. Nonetheless, these conditions (or strategies) must be instantiated for a particular domain.

The next set of discriminations involve distinguishing between instantiations of domain-independent instructional strategies and domain-dependent instructional strategies. After considerable effort to develop counter examples, we have agreed that we have found no domain-dependent instructional strategies that could not just as well be called domain-specific instantiations of domain-independent instructional strategies. This finding may counter some work on problem solving in cognitive science. However, we believe that while task requirements differ enormously, task-specific instruction is best conceived of as instantiations of domain-independent instructional strategies rather than as domain-dependent instructional strategies unique to the particular domain. In fact, the differences among domain-independent and domain-specific instantiations of strategies are not hard and fast, and, undoubtedly, share space on the same continuum. A review by Alexander and Judy (1988) provides an excellent source for the literature on this issue.

For this work we have chosen the teaching of a cognitive strategy (i.e., visualization) for the following reasons: (1) it is appropriate for ICAI technology; (2) it will facilitate the teaching of domain-specific knowledge of advection and (3) is considered a domain-independent strategy; and (4) the approach was viewed as feasible by the Air Force subject matter experts in weather. The domain-independent instructional strategy (or in Gagné's terms, learning conditions[1]) for teaching

[1] These conditions are, in Gagné's terminology, "instructional events" which distinguish the teaching of cognitive strategies from teaching other types of learning outcomes.

a cognitive strategy are shown in Table 1. An earlier version of this strategy was invented by Dr. Robert Gagné and modified for this project. Table 2 presents an instantiation of this instructional strategy to teach visualization.

TABLE 1

INSTRUCTIONAL STRATEGY TO TEACH A COGNITIVE STRATEGY

1. Communicate the function and utility of the strategy.
2. Communicate the context in which the strategy will be used.
3. Confirm or teach subordinate skills.
4. Describe and demonstrate the cognitive task strategy.
5. Provide practice with feedback, using a variety of *novel* problems requiring the strategy taught.

TABLE 2

INSTRUCTIONAL STRATEGY TO TEACH VISUALIZATION

1. Communicate the function and utility of the visualization strategy.
2. Communicate the weather context (i.e., advection) in which the strategy will be used.
3. Confirm or teach subordinate skills.
   - associated non-spatial knowledge
     - — temperature advection principle; thickness chart concept; Isotherm facts
   - conventions of instructors
     - — different visual metaphors for different concepts (e.g., fishtank)
4. Describe and demonstrate the cognitive strategies.
   - imagery (visualizing strategy)
     - — present 2-D diagram
     - — tell student to imagine 3-D
     - — present 2-D diagram with 3-D visualization on computer(motion, color, HOOPS)
5. Provide practice with feedback, using a variety of *novel* problems requiring the strategy taught.

In summary, the instructional outline in Table 2 presents a domain-independent instructional strategy (Entries 1-5) for teaching the cognitive strategy of visualization. The sequence they would be taught is 1–5. Step "Describe and Demonstrate the Cognitive Task Strategy" (Entry 4 in Table 2) are cognitive strategies that experts use to solve the objective. They were derived from the literature on land navigation (e.g., Tkacz, 1987; Simutis & Barsam, 1984; Thorndyke & Stasz,

1979; Lohman & Kyllonen, 1983; Schwartz & Kulhavy, 1988; Thorndyke & Hayes-Roth, 1986) and validated during our knowledge elicitation at Chanute. We surveyed the literature on visualization to find an explicit strategy to teach visualization. The literature concludes that visualization strategies are helpful, useful and should be taught but give very little information of the procedures to follow to teach visualization. Generaly, visualization strategies are cognitive strategies with embedded principles and procedures. We view the teaching of these cognitive task strategies as using a modified version of Merrill's Component Display Theory (Merrill, 1987). Merrill suggests to add secondary presentation forms to the primary instruction to enhance learning. Secondary presentation forms could be contexual elaborations, mnemonics, attention focusing devices, or alternate forms of presentation. In some cases, we added visualization to the primary instruction in the form of secondary presentation. Gagné's suggestion of how to teach a visualization strategy was followed of: present 2-D diagram, then tell the learner to visualize in head (imagine), then present the diagram with the 3-D visualization mechanism (e.g., HOOPS). In Table 2, the domain-independent instructional sequence is provided in list format since this is clearer and more efficient than rule format for communicating macro sequences. The rules which sequence items in this list are "housekeeping"—not instructional—and would be devised by the implementor.

Implementation Issues and Wrap-Around Design

In the projected intelligent tutoring system, students would be taught a cognition strategy of visualization using the instructional strategy found in Table 2 (Entries 1, 4, and 5). Since our one-hour application is to teach such a visualization strategy in the context of advection, a pretest would be needed to screen out any students who do not have the prerequisite facts, concepts, procedures and skills. Students experienced in advection problems should get a perfect pretest score, barring error. A pretest of visualization will also be given (i.e., from the French Kit, see Appendix B). We hypothesize that in order for our visualization instruction to work a student must have at least a

minimum score on the visualization test. Students who do not have such as score will be screened out. Finally, a 5-item test of anxiety (Morris, et al., 1982) will be given. The purpose of this test is to serve as both a baseline measure of anxiety and also, for the posttest measure of anxiety, a criterion measure. The items are provided in Appendix C. We wish to ensure that our instructional interventions are not causing anxiety (Sieber, O'Neil & Tobias, 1977). It is expected that anxiety will be low.

Sequencing and Learner Control

In our design, both macro and micro sequencing issues are addressed. In general, sequencing suggestions are provided in an ordered list format since this format is clearer and more efficient than rule format for communicating macro sequences. An implementor should note the implicit macro sequencing information in Table 2. Instructional activities are taught in the order in which they appear. Micro sequencing for teaching the task strategies is indicated in specific rules. The rules which sequence items in these lists (see Tables 2, 3, 4) are "housekeeping"—not instructional and would be devised by the implementor.

The recommended domain-independent macro instructional sequence is presented in Table 3. A first cut of the instantiation in the domain of advection is presented in Table 4. As shown in Table 4, learner control is suggested as a micro strategy during instruction (Merrill, 1983). Learner control includes giving the student the list of instructional topics and allowing the student to choose the topic and the pace to go through the instruction. No learner control, or system control, refers to having the system control the instruction, making decisions about topics, practice, and when to advance to the next difficulty level or the next topic.

Learner control should be given to students scoring above the 25th quartile on the knowledge test. Students scoring below the 25th quartile should not be given learner control. Also, students that require remediation should not be given learner control. Therefore, if a student scored high on

Table 3

MACRO INSTRUCTIONAL SEQUENCE

Pretest
Instruction
Remediation
Posttest

the knowledge test and got learner control but then required remediation, learner control should be changed to system control.

Instructional Strategy Rule Set

This section presents selected examples of instructional strategy rules. The terminal objective of the rule set is for the learner to acquire and apply the visualization cognitive strategy in the domain of advection. The task strategies are taught as an expert approach to determine the expected vertical motion of air at a specific geographical location. Application of the task strategies plus use of selected subordinate concepts and facts is also provided.The next section provides an instantiated instructional interaction to illustrate their function. Table 6 provides a "cross-walk" of the rules and their instantiations in this report. The rule set includes instructional rules, remediation rules, pretest rules and posttest rules. The instantiated rules do not provide an instructional sequence for teaching temperature advection. Rather, they provide examples of instantiation of the domain independent rules in the specific domain of temperature advection. The sequencing of the rules will be determined when all the domain knowledge is added (i.e., courseware) as well as bookkeeping rules. This is to be added by the implementor.

Table 4

DETAILED MACRO INSTRUCTIONAL SEQUENCE

Pretest

- Text for anxiety
- Test of visualization (French Kit)
- Test for prerequisites (instructor, Go/NoGo, multiple choice)

Instruction

- Objective
- Teach visualization via Gagné strategy (Table 2)
  - Embedded procedure
  - Determining PVA or NVA and WAA or CAA or unknown
  - Use matrix to determine expected vertical motion base on joint occurrence of Step 1
  - Check counter examples (e.g., mountains or time of year)
- Successive presentation (2D→3D; HOOPS; compactdisc) to provide practice
- Motion
- Learner control unless in bottom quartile of domain knowledge

Remediation (specific error-driven)

- Potential prerequisites
  - Solid vs dotted lines
  - Advection box
  - Buys—ballot law
- Instruction not mastered
- No learner control

Posttest

- Test for mastery
- Test for Anxiety (Morris, et al., 1982)
- Test for visualization (French Kit)

Table 5. CROSS WALK AMONG RULES AND INSTANTIATIONS

	Rule ID	Rule	Instantiation
Pretest rules			
	2000	Figure 1	
	2001	Figure 2	
	2002	Figure 3	
	2003	Figure 4	
	2004	Figure 5	
	2005	Figure 6	
	2006	Figure 7 (looping)	
	2007	Figure 8	
	2008	Figure 9	
	2009	Figure 10	
Use-Principle			
	3107	Figure 11	Figure 37
	3108	Figure 12	Figure 38
	3108a	Figure 13	Figure 39
	3108b	Figure 13a	Figure 39a
	3114	Figure 14	Figure 40
	3114a	Figure 15	Figure 41
	3108b	Figure 13a	Figure 41a
	3114b	Figure 16	Figure 42
	3108b	Figure 13a	Figure 42a
	3114c	Figure 17	Figure 43
	3419	Figure 26	Figure 44 (remediation)
	3420	Figure 27	Figure 45
	3421	Figure 28	Figure 46
	3422	Figure 29	Figure 47
	3108b	Figure 13a	Figure 47a
	3425	Figure 30	Figure 48
Use-Procedure			
	3114d	Figure 18	Figure 49
	3114e	Figure 19	Figure 50
	3114f	Figure 20	Figure 51

	Rule ID	Rule	Instantiation
	3114g	Figure 21	Figure 52
	3419	Figure 26	Figure 53 (remediation)
	3420	Figure 27	Figure 54
	3421	Figure 28	Figure 55
	3422	Figure 29	Figure 56
	3108b	Figure 13a	Figure 56a
	3425	Figure 30	Figure 57
Use-Concept			
	3411	Figure 22	Figure 58
	3412a	Figure 23	Figure 59
	3416	Figure 24	Figure 60
	3416A	Figure 25	Figure 61
	3419	Figure 26	Figure 62 (remediation)
	3420	Figure 27	Figure 63
	3421	Figure 28	Figure 64
	3422	Figure 29	Figure 65
	3425	Figure 30	Figure 66
Remember-Fact			
	3400	Figure 31	Figure 67
	3402	Figure 32	Figure 68
	3406	Figure 33	Figure 69
	3419	Figure 26	Figure 70 (remediation)
	3420	Figure 27	Figure 71
	3421	Figure 28	Figure 72
	3422	Figure 29	Figure 73
	3425	Figure 30	Figure 74
Posttest Rules			
	4000	Figure 34	
	4001	Figure 35	
	2006	Figure 7 (looping)	
	2007	Figure 8	
	2008	Figure 9	
	2009	Figure 10	

Domain-Independent Strategy Rules: Primary Instruction

The following rules are primary instructional rules of Use-Principle for entry 3 (Table 2). Each rule is provided as a figure with the following format conventions:

1. Rule Identification Number (Rule ID:);
2. Statement of the Rule in English as an If...Then condition action pair;
3. A comment to provide an instructional design explanation ("Comment"); and
4. A Reference in American Psychological Association Format ("Reference") provides the best "evidence" reference (Ref) for a rule. In some cases the rule reflects a synthesis of several studies and thus several references are provided.

The Component Display Theory prescriptions for teaching use-principles for the teaching of task strategies could be implemented in the forms of discovery, simulation, conversational tutorial, and expository tutorial (Merrill, 1987). This report specifies the rules for expository tutorial mode (Rules 3107, 3108, 3114).

Some terminology from Merrill (1987) may assist the reader unfamiliar with Component Display Theory to interpret the rules: *Component Display Theory* provides several useful distinctions in a performance-content classification system and a set of instructional prescriptions tie to the classification system. Merrill views content as consisting of facts (e.g., association between date and name), concepts (set of objects that share common characteristics), procedure (set of steps to carry our an activity), and principles (e.g., cause and effect relationships in a process). The performance of a person is either to remember or use (apply a generality to a specific case) or to find content (find or invent a new generality). A *generality (rule)* is a statement of a definition, principle, or the steps in a procedure. An instance *(example)* is a specific illustration of an object, symbol, event, process, or procedure . . . *Expository* means to present, tell, or show; *inquisitory* means to question, ask, or require practice. CDT also makes the distinction between primary presentation forms (rule, example, practice) and secondary

presentation forms which supplement them and which may be attention focussing devices, prerequisite information, or alternative representations.

Concluding Remarks

In summary, this third technical deliverable was our final report for the instructional design aspects of our subcontract. The report provided an iterative update for our prior technical deliverables (e.g., O'Neil & Jacoby, 1990). We chose to implement an iterative process to accomplish our milestones for Task 3 as specified in the Expert-EASE/ADI proposal (see Appendix A, which is page 34 of the Expert-EASE Proposal). This third technical deliverable augmented the second technical deliverable in the following manner: (a) most drawings were presented in computer-readable form; (b) general rules for teaching visualization were provided; (c) remediation rules for teaching visualization were provided; (d) all multiple choice instantiations have four options; (e) all references were provided; (f) suggestions for adding color and motion were provided.

Our next deliverable on our subcontract will provide the evaluation plan.

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APPENDIX A

TASK 3. INSTRUCTIONAL STRATEGY

Task 3. INSTRUCTIONAL STRATEGY

Objective:

- To develop a domain-independent instructional strategy for the ITS and instantiate it for the weather training problem. The domain-independent strategy determines the underlying design of the ITS knowledge base, while the instantiation determines the specific nature of the rule base.

Input:

- Visits to Chanute for interview with students and teachers.
- Design specifications from Task 1 and interim versions of the software.

Approach:

- Advance Design Information (ADI) will be responsible for this task and the results will be implemented by EES as part of the other tasks. Tasks 3 and 4 will run concurrently to encourage an incremental development and allow for continuous communication between EES and ADI on the effort.
- This task consists of the design and implementation of the ITS application for the analysis of Air Column Motion.
- ADI will provide the domain-independent instructional strategy that will drive the expert tutor for one family of tasks (i.e., problem solving in weather analysis). ADI will provide rules for this strategy in the form shown in Table 3 and they will provide a specific instantiation of this strategy. They will further provide instantiations for the teaching of the task strategy. ADI will also provide an on-going review of all aspects of the tutor development, based upon an instructional perspective.
- The rule structure and their instantiations will be delivered to EES in letter form, with the data in a format to be jointly determined by EES and ADI. Although this deliverable will not be computer-compatible code, it will constitute ADI's best effort to provide complete and sufficient knowledge bases to perform the instructional tasks required of the tutor. Once this framework is established, the gaps can be filled in to provide a draft of the complete knowledge base.
- ADI will prepare a design for the instructional wrap-around materials (pretest, posttest, remediation of one prerequisite concept or procedure, student handout, instructor handout) that will be developed in Task 7.

Results:

- Instructional strategy in paper form and design for wrap-around material.

Milestones:

3.1 Rule set in paper format to implement design structure.

3.2 Instantiations in paper format to implement instructional strategy.

3.3 Design for instructional wrap-around materials.

APPENDIX B

FRENCH KIT

MANUAL FOR KIT OF FACTOR-REFERENCED COGNITIVE TESTS 1976

The tests described in this manual are distributed for research use only. They should not be used for counseling or other operational purposes.

Ruth B. Ekstrom
John W. French
Harry H. Harman
with Diran Dermen

Office of Naval Research Contract N00014-71-C-0117
Project Designation NR 150 329
Harry H. Harman, Principal Investigator

Educational Testing Service
Princeton, New Jersey

August 1976

VZ VISUALIZATION

Factor

The ability to manipulate or transform the image of spatial patterns into other arrangements

The visualization and spatial orientation factors are similar but visualization requires that the figure be mentally resturctured into components for manipulation while the whole figure is manipulated in spatial orientation. Some researchers think that visualization is a more difficult or more complex and less speeded form of spatial orientation.

Cattell (1971) does not accept visualization as a primary factor. He suggests that it is a second-order factor which includes spatial ability, figural adaptive flexibility, speed of closure, and flexibility of closure. Royce (1973) suggests both primary and higher order visualization factors.

As Carroll (1974) has pointed out, both visualization and spatial orientation require the mental rotation of a spatial configuration in short-term visual memory; visualization requires the additional component of performing serial operations.

Some subjects may employ an analytic strategy in visualization tests and search for symmetry and planes of reflection as clues to the solution. Shepard and Feng (1972) have described the mental processes involved in paper-folding tests.

Identification: Guilford, CFT

References: 3, 7, 13, 18, 21, 39, 45, 52, 58, 60, 67, 69, 73, 79, 85, 86, 90, 91, 93, 100, 103, 108, 110, 121, 130, 143, 153, 156, 161, 164, 165, 174, 197, 200, 207, and 209.

Tests

Form Board Test -- VZ-1

Each item presents 5 shaded drawings of pieces, some or all of which can be put together to form a figure presented in outline form. The task is to indicate which of the pieces, when fitted together, would form the outline.

Length of each part: 24 items, 8 minutes

Suitable for grades 9-16

Paper Folding Test -- VZ-2

Suggested by Thurstone's Punched Holes. For each item successive drawings illustrate two or three folds made in a square sheet of paper. The final drawing of the folded paper shows where a hole is punched in it. The subject selects one of 5 drawings to show how the punched sheet would appear when fully reopened.

Length of each part: 10 items, 3 minutes

Suitable for grades 9-16

Surface Development Test -- VZ-3

Suggested by Thurstone's test of the same name. In this test, drawings are presented of solid forms that could be made with paper or sheet metal. With each drawing there is a diagram showing how a piece of paper might be cut and folded so as to make the solid form. Dotted lines show where the paper is folded. One part of the diagram is marked to correspond to a marked surface in the drawing. The subject is to indicate which lettered edges in the drawing correspond to numbered edges or dotted lines in the diagram.

Length of each part: 5 items in each of 6 drawings, 6 minutes

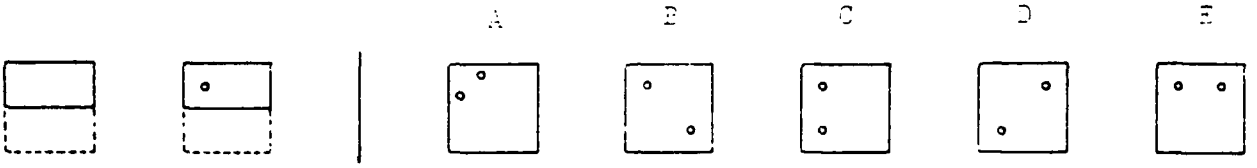
Suitable for grades 9-16

Name _____

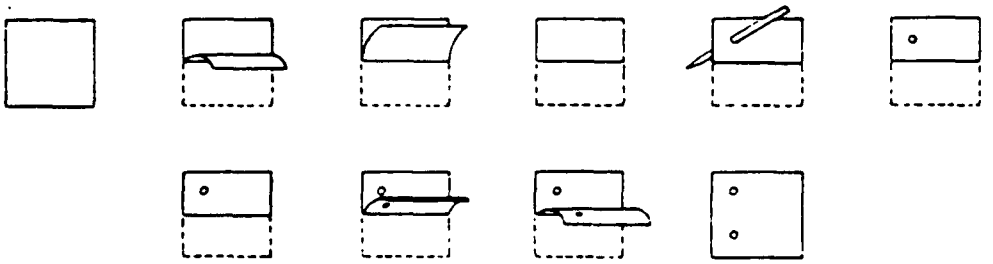
PAPER FOLDING TEST — VZ-2

In this test you are to imagine the folding and unfolding of pieces of paper. In each problem in the test there are some figures drawn at the left of a vertical line and there are others drawn at the right of the line. The figures at the left represent a square piece of paper being folded, and the last of these figures has one or two small circles drawn on it to show where the paper has been punched. Each hole is punched through all the thicknesses of paper at that point. One of the five figures at the right of the vertical line shows where the holes will be when the paper is completely unfolded. You are to decide which one of these figures is correct and draw an X through that figure.

Now try the sample problem below. In this problem only one hole was punched in the folded paper.



The correct answer to the sample problem above is C and so it should have been marked with an X. The figures below show how the paper was folded and why C is the correct answer.



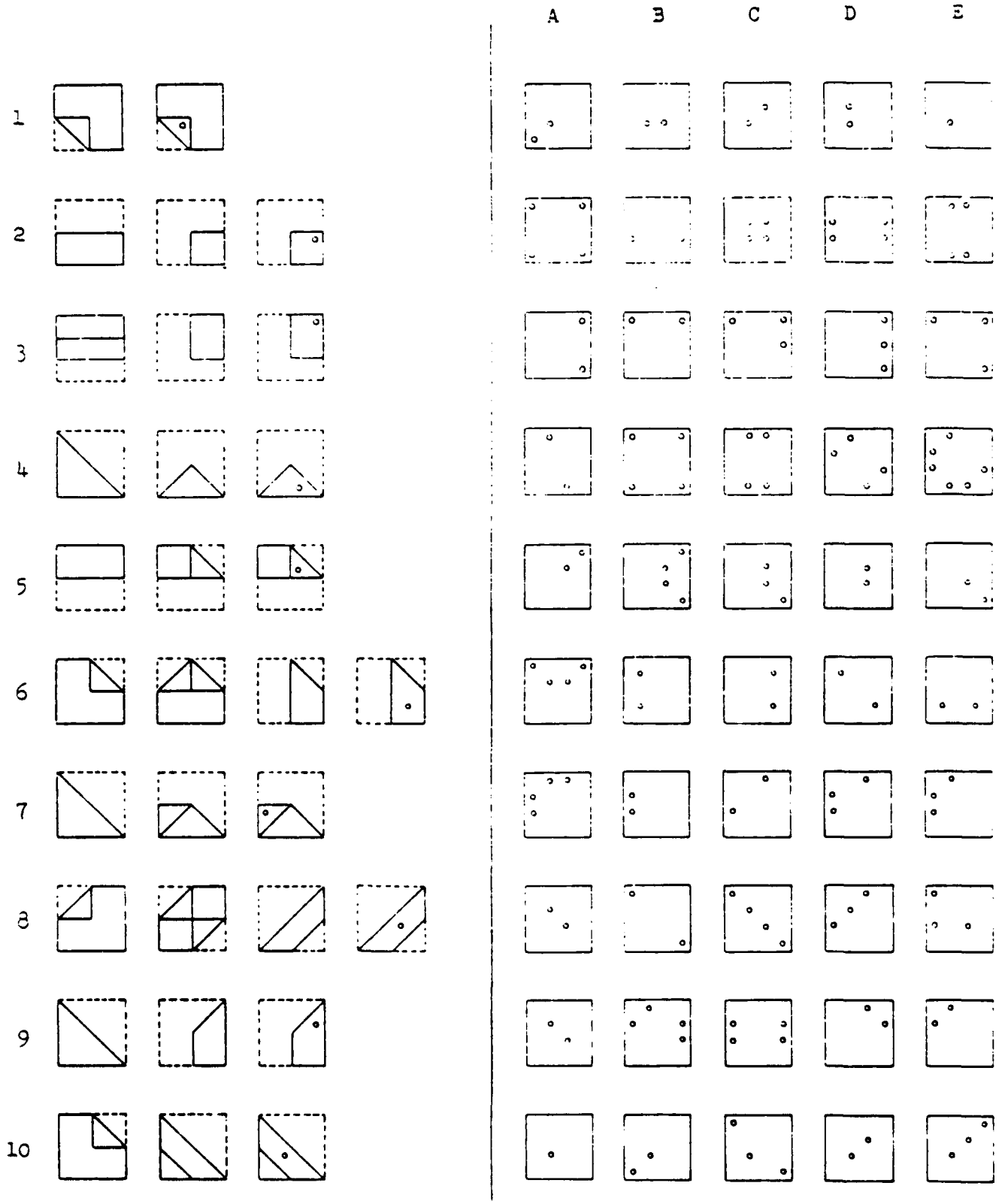
In these problems all of the folds that are made are shown in the figures at the left of the line, and the paper is not turned or moved in any way except to make the folds shown in the figures. Remember, the answer is the figure that shows the positions of the holes when the paper is completely unfolded.

Your score on this test will be the number marked correctly minus a fraction of the number marked incorrectly. Therefore, it will not be to your advantage to guess unless you are able to eliminate one or more of the answer choices as wrong.

You will have 3 minutes for each of the two parts of this test. Each part has 1 page. When you have finished Part 1, STOP. Please do not go on to Part 2 until you are asked to do so.

DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO.

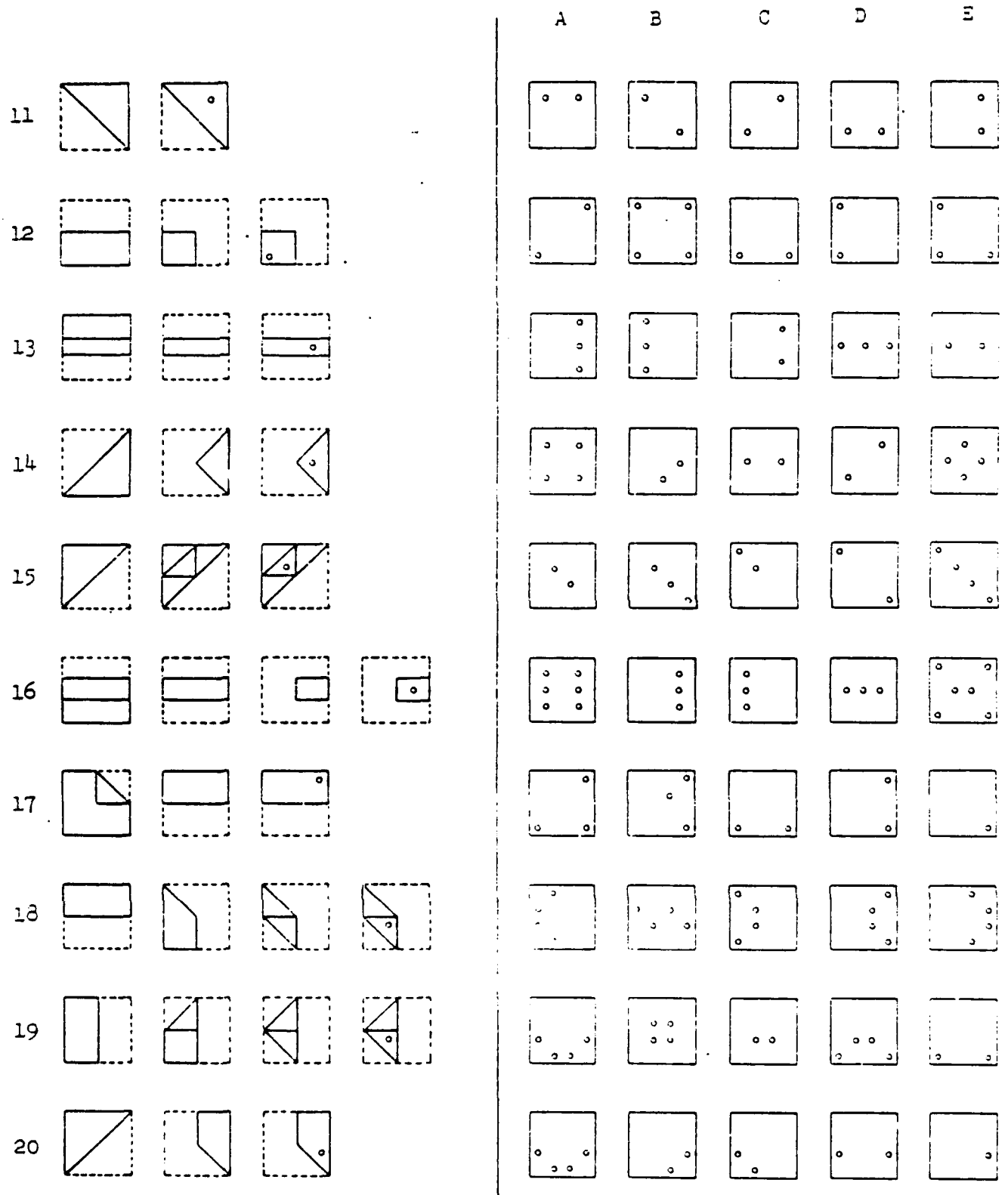
Part 1 (5 minutes



DO NOT GO ON TO THE NEXT PAGE UNTIL ASKED TO DO SO.

STOP.

Part 2 (3 minutes)



DO NOT GO BACK TO PART 1, AND

DO NOT GO ON TO ANY OTHER TEST UNTIL ASKED TO DO SO. STOP.

APPENDIX C

POST-TEST QUESTIONAIRE

Post-Test Questionnaire

To the right of each of the statements below, indicate your feelings, attitudes, or thoughts as they were when you were taking the test. Circle the number of your answer beside each sentence, using the scale below. Remember to indicate how you ***felt.***

Scale

1. The statement does not describe my condition at the time.
2. The condition was barely noticeable.
3. The condition was moderate.
4. The condition was strong.
5. The condition was very strong; the statement describes my condition at the time very well.

1.	I felt regretful.	1	2	3	4	5
2.	I was afraid that I should have studied more for this test.	1	2	3	4	5
3.	I felt that others would be disappointed in me.	1	2	3	4	5
4.	I felt I may not do as well on this test as I could.	1	2	3	4	5
5.	I did not feel very confident about my performance on this test.	1	2	3	4	5

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Figure 1. Start Pretest

Rule ID: 2000

If
{goal: start}
then
{assert goal: start anxiety test}

Comment: Three pretests will be given: anxiety test, visualization test and prerequisit knowledge test. The tests will be given in the above order. The student will take the next test only if he passed the criteria for the given test. Students scoring too low on the test will be refered to the instructor. Students scoring above criteria on both the visualization and the prerequisit knowledge test, will not need the instruction.

Figure 2

Rule ID: 2001

If
{total score anxiety test < ?criteria}
then
{assert goal: start visualization test}

Figure 3

Rule ID: 2002

If
{total score visualization test > ?criteria}
then
{assert goal: start prerequisite test}

Figure 4

Rule ID: 2003

If

{total score prerequisite test > ?criteria}

then

{assert goal: start instruction}

Figure 5: Refer to Instructor

Rule ID: 2004

If

{didn't meet criteria}

then

{see instructor}

Figure 6: If High Score, No Instruction

Rule ID: 2005

If

{and {total score visualization test > ?max-criteria}
{total score prerequisite test > ?max-criteria}

then

{don't do instruction}

Figure 7: Start Test

Rule ID: 2006

```
If
        {goal: start ?test}
then
        {and {give first item of test}
             {assert goal: continue ?test}}
```

Figure 8: Loop Through Test Items

Rule ID: 2007

```
If
        {and {goal: continue ?test}
             {more test items}}
then
        {give next item of ?test}
```

Figure 9: Accumulating test scores

Rule ID: 2008

```
If
        {item ?test answered correctly}
then
        {adjust score of ?test to score + 1}
```

Figure 10: Total Test Score

Rule ID: 2009

```
If
        {no more items}
then
        {total score = score}
```

Figure 11. Expository Tutorial Rule

Rule ID: 3107

```
if
                {goal: apply Expository Tutorial for ?x}
then
        and  {  {assert goal: display Expository Generality for
                    expository tutorial of ?x}
                {assert goal: display Expository Instance for
                    expository tutorial of ?x}
                {assert goal: display Inquisitory Instance for
                    expository tutorial of ?x}
             }
```

Comment: For use-level performance, the presentation should consist of an expository generality (rule) followed by a set of expository instances, followed by a set of previously unencountered inquisitory instances (practice).

Reference: Merrill, M.D. (1983) Component Display Theory. In C.M. Reigeluth (Ed.), "Instructional Design Theory and Models: An Overview of Their Current Status", Hillsdale, New Jersey, Lawrence Erlbaum Associates.

Figure 12. Expository Generality Rule

Rule ID: 3108

if

and { goal: display expository
generality for expository tutorial of ?x}
{content representation of ?x is in the form of a
procedure for using a principle}
}

then

and { {display: name/definition of principle ?x}
{assert goal: display secondary presentation of ?x}
{display: any prerequisite concept(s) of ?x}
{display: prerequisite procedure in which
principle ?x is applied}
}

Comment: This strategy is an adaptation of the event chain strategy from Component Display Theory.

Reference: Merrill, M.D. (1983) Component Display Theory. In C.M. Reigeluth (Ed.), "Instructional Design Theory and Models: An Overview of Their Current Status," Hillsdale New Jersey, Lawrence Erlbaum Associates.

Figure 13: Secondary Presentation

Rule ID: 3108a

If
{goal: display secondary presentation of ?x}
then
{and/or {dispay: contexual elaboration of ?x}
{dispay: mnemonics of ?x}
{display: attention focusing devices of ?x}
{display: alternate forms of representation of ?x}
{assert goal: vizualization}
}

Comment: Secondary presentations are additional information the instructor might want to add, in this case after presentation of a generality. Secondary presentation following a presentation of a generality may be contexual elaboration, mnemonics, attention focusing devices, or alternate form of representation. The elaboration can include one or more of the above forms.

Reference: Merrill, M.D. (1983) Component Display Theory. In C.M. Reigeluth (Ed.), "Instructional Design Theory and Models: An Overview of Their Current Status," Hillsdale New Jersey, Lawrence Erlbaum Associates.

Figure 13a: Visualization rule

Rule ID: 3108b

If
{goal: visualization }
then
{and { display: appropriate 2-D drawing or graph or diagram}
{ display: instructions to imagine movement/visualization}
{display: movement}
{display: color}
}

Comment: Implementor to provide animation for movement and color according to suggestions when appropriate.

Figure 14. Expository Generality Elaboration Rule

ID: 3114

if

{goal: display Expository Generality for expository tutorial of ?x}

then {highlight the concepts involved in the principle ?x}

Comment: Expository Generality elaboration can also appear in the form of help (attention focus device), and prerequisite information (related fact, concept, principle, procedure).

Reference: Merrill, M.D. (1983) Component Display Theory. In C.M. Reigeluth (Ed.), "Instructional Design Theory and Models: An Overview of Their Current Status"

Figure 15. Expository Instance Rule

Rule ID: 3114a

If

{and {goal: display expository instance for expository tutorial of ?x}
{content representation of ?x is in the form of a procedure for using a principle}
}

then

{and {display: name of principle ?x}
{display: an example where principle ?x is applied to a specific situation}
{assert goal: visualization}
}

Comment:: An expository instance for use- principle should consists of the name of the principle, a situation and representation where the principle is applied.

Reference: Merrill (1983, 1987)

Figure 16. Another Expository Instance

Rule ID: 3114b

If

{and {goal: display expository instance for expository tutorial of ?x}
{principle ?x will be applied to a variety of situations}
{an instance of principle ?x is already presented}
}

then

{and {display: the next instance where principle ?x is applied to a different situation than the ones already presented}
{assert goal: visualization}
}

Comment: The instances for a particular generality should be divergent. If the rule is applied, then it is probable that the sample of instances presented will be representative of the population of instances that may be encountered in the real world.

Reference: Merrill, M.D. (1983) Component Display Theory. In C.M. Reigeluth (Ed.), "Instructional Design Theory and Models: An Overview of Their Current Status"

Figure 17. Switch to Remediation Mode Rule

Rule ID: 3114c

If

{goal: display inquisitory instance for expository tutorial of ?x}

then

{assert goal: remediation mode }

USE - PROCEDURE RULES

The following set of rules are used to teach using a procedure (Rule ID: 3114d–3114g).

Figure 18. Use Procedure Rule

Rule ID: 3114d

If

{goal: teach Use Procedure ?p}

then

and { { assert goal: display expository generality of procedure ?p}
{ assert goal: display expository instance of procedure ?p}
{ assert goal: display inquisitory instance of procedure ?p}
}

Comment: For use-level performance, the presentation should consist of an expository generality (rule) followed by a set of expository instances, followed by a set of previously unencountered inquisitory instances (practice).

Refernce: Merrill (1983,1987)

Figure 19. Expository Generality Rule

Rule ID: 3114e

If

and { {goal: display expository generality of procedure ?p}
{content representation of ?p is in the form of a procedure}
}

then

and { {display: name/goal of procedure ?p}
{display: steps of procedure ?p}
{display: order of procedure ?p}
{display: decision/branch process of procedure ?p}
}.

Comment: This strategy is an adaptation of the event chain strategy from CDT.

Reference: Merrill (1983, 1987).

Figure 20. Expository Instance Rule

Rule ID: 3114f

If

{goal: display expository instance of procedure ?p}

then

and { {display: name/goal of procedure ?p}
{display: materials of procedure ?p
{display: a demonstration of the execution of procedure ?p}
{display: the representation of procedure ?p}
}

Comment: This strategy is an adaptation of the event chain strategy from CDT.

Reference: Merrill (1983, 1987).

Figure 21. Inquisitory Instance of Procedure

Rule ID: 3114g

If

{goal: display inquisitory instance of procedure ?p}

then

{assert goal: remediation mode}

USE CONCEPT RULES

The following set of rules are used to teach using a concept (Rule ID: 3411-3425)

Figure 22. Use-Concept Rule

Rule ID: 3411

if {goal: teach Use-Concept ?concept}

then
and { {assert goal: display Expository Generality of ?concept}
{assert goal: display one Expository Instance of ?concept}
{assert goal: display Inquisitory Instance of ?concept}
}

Comment: For Use-Concept level performance, the presentation should consist of an expository generality followed by a set of expository instances or examples, followed by a set of previously unencountered inquisitory instances (practice) consisting of several additional instances different from the instances used for the expository instances.

Reference: Merrill (1983, 1987)

Figure 23 Expository Generality of Concept Rules

Rule ID: 3412a

if {goal: display Expository Generality of ?concept}

then
and { {display: name of ?concept}
{display: superordinate concepts of ?concept}
{display: all the relevant attributes of ?concept and relationship of attributes}
{display: best example along with the definition of ?concept}
}

Comment: The Expository Generality should consist of the name and the definition of the concept. The definition should include identification of the superordinate class, the relevant attributes that distinguish instances of this concept from coordinate concepts within the same superordinate class, and the relationship of these attributes to one another. A best example should be presented along with the definition of the concept (Park & Tennyson, 1986). Merrill calls the best example the "Reference Example." In his sample lesson (Merrill, 1987, p. 212) the reference example is presented along with the definition.

References: (Merrill, 1983, 1987; Merrill & Tennyson, 1977, 1978; Park and Tennyson, 1986).

Figure 24. Match Example of Concept Rule

Rule ID: 3416

if {goal: display Expository Instance of ?concept}

then {display: example with a matched non-example}

Comment: This is the match rule in Component Display Theory

Reference: Merrill, (1983).

Figure 25. Inquisitory Instance for Use Concept

Rule ID: 3416A

If
{goal: display Inquisitory instance of ?concept}
then
{assert goal: remediation mode}

REMEDIATION RULES FOR PRINCIPLE PROCEDURE AND CONCEPT

Domain-Independent Strategy: Remediation

This subsection contains rules for remediation in recall and use of the task strategy principles and subordinate concepts and facts. The rules are provided as a figure with the same format conventions as the prior subsection. Then particular rules are error-driven.

Figure 26 Display Easier Instance Rule

Rule ID: 3419

if
and { {goal: remediation mode}
{goal: display Inquisitory Instance of ?a}
{it is the first time the goal is set for the current content}
}
then
{display: an instance in the first rational set with fewest number of relevant attributes}

Comment: In teaching, one measure of difficulty is the number of relevant attributes for a specific content. The instance with the least number of attributes is the one easiest to be classified.

Reference: (Merrill & Tennyson, 1978, Tennyson & Park, 1980).

Figure 27

Rule ID: 3420

If
and { {goal: display inquisitory instance of ?a}
{the learner answered the current instance correctly}
{at the same dificulty level, instances in some rational set have not been presented or have not been answered correctly}
}
then
{display: a different instance in the same rational set}

Figure 28 Optional Instance Presentation

Rule ID: 3421

if
and { {goal: display Inquisitory Instance of ?a}
{the learner answers the instance correctly}
{the learner answers all the instances at the same difficulty level correctly}
}

then
{display: an instance from a rational set
different from the current one at a higher difficulty level}

Comment: An optional instance presentation sequence in Park and Tennyson's (1986) works to present an inquisitory instance (interrogatory example) of any other instance in the rational set if the learner answers the current one correctly but the mastery level is not yet reached.

Reference: Park and Tennyson (1986)

Figure 29 Switch from Inquisitory to Expository Instance

Rule ID: 3422

if
{and {goal: display Inquisitory Instance of ?a}
{the learner answers the instance incorrectly}
}

then {and {display: an instance in the same rational set in Expository mode}
{assert goal: visualization}
}

Comment: Present another example of the same content in an expository form if the learner's classification on a given interrogatory example is incorrect.

Reference: Park and Tennyson (1986)

Figure 30 Instances to Predict Mastery

Rule ID: 3425

if
and { {goal: display Inquisitory Instance of ?a}
{the number of instances that is already presented is larger than 4}
{the learner's score is larger than the criterion}
}

then
and { {the learner reached mastery level}
{instruction on the set is completed}
}

Comment: A minimum of four instances is necessary before predicting mastery at any given criterion level (Tennyson, 1984).

Reference: Tennyson, 1984

REMEMBER FACT RULES

The following set of rules are used to teach remember fact. (Rule ID: 3400-34-6)

Figure 31

Rule ID: 3400

if {goal : teach Remember-Fact}

then

and { {assert goal : display Expository Instance for ?fact}
{assert goal: display Inquisitory Instance for ?fact}
}

Comment: "For remember-fact performance, the presentation should consist of a set of expository instances of all the facts to be taught, followed by a set of inquisitory instances (practice)" (Merrill, 1983, p. 312).

References: Merrill, M.D. (1983). Component Display Theory. In C.M. Reigeluth (Ed.), *Instructional design theories in action: Lessons illustrating seleted theories.* Hillsdale, NJ: Lawrence Erlbaum.

Also Merrill (1987) a lesson based on the Component Display Theory. In C.M. Reigeluth (Ed.) *Instructional design theories in action: Lessons illustrating seleted theories.* Hillsdale, NJ: Lawrence Erlbaum.

Figure 32

Rule ID: 3402

if

and { {goal: display Expository Instance for ?fact}
{the facts can be organized into a group in some
meaningful way such as by time, space, events, etc.}
{NOT all the facts in the group are new knowledge to the learner}
}

then

{display: the new facts and relate them to the prior knowledge (known facts) of the learner}

Comment: It is important to create a meaningful learning environment so that the learner can relate what is being learned to what the learner knows. The facts within the same group are good devices to help bring about meaningful learning.

Reference: Merrill (1987) a lesson based on the Component Display Theory. In C.M. Reigeluth (Ed.), Instructional design theories in action: Lessons illustrating selected theories. Hillsdale, NJ: Lawrence Erlbaum Associates.

Figure 33

Rule ID: 3406

if

{goal: display Inquisitory Instance for facts}

then

{assert goal: remediation mode}

Comment: "Subsequent practice trials should present the set of pairs to be associated in random order (Merrill, 1987, p. 234)."

Reference: Merrill (1987) a lesson based on the Component Display Theory. In C.M. Reigeluth (Ed.), Instructional design theories in action: Lessons illustrating selected theories. Hillsdale, NJ: Lawrence Erlbaum Associates.

Figure 34: Posttest Rule

Rule ID: 4000

if

{end of instruction}

then

{and {assert goal: start knowledge test}
{assert goal: start anxiety test}
{assert goal: start visualization test}
}

Comment: the three posttest will be given regardless of the student's score. The order of the tests is: knowledge test, anxiety test and visualization test. The same looping rules used for the pretest will be used to give the posttests.

Figure 35

Rule ID: 4000

if

{total score knowledge test < ?criteria}

then

{refer to instructor

Comment: Students not passing the knowledge test after the instruction should be refered to the instructor.

Instructional Instantiations

The format of presentation for the instantiations is a sequential list consisting of: (1) assertions based on prior system actions or data (e.g. tutorial subgoals), (2) consequently triggered, instantiated rules, (3) resulting displays, and (4) learner responses. Goal-removing consequences of rules can be inferred in most cases and are not stated explicitly. The instructional

goal is to Teach use-principle describe and demonstrate the temperature advection principle. In addition, the rules for using the procedures of the concept of thickness chart and remembering the fact of Isotherms are provided.

Figure 36

Instantiation of Rule ID: Table 2 Strategy

```
if
      and  {     {goal: teach temperature advection }
                       {knowledge communication temperature advection has not been presented}
                 }
then
      and  {     {assert goal: apply expository tutorial for temperature advection}
                       {assert goal: content representation temperature advection
                        is in the form of a procedure for using a principle}
                 }
```

Figure 37

Instantiation of Rule ID: 3107

```
if
                 { goal: apply expository tutorial for temperature advection}
then
      and  {     {assert goal: display expository generality for expository
                       tutorial of temperature advection}
                       {assert goal: display expository instance for expository
                        tutorial of temperature advection}
                       {assert goal: display inquisitory instance for expository
                        tutorial of temperature advection}
                 }
```

Figure 38

Instantiation of Rule ID: 3108

```
if
        and  {    {goal: display expository generality for expository tutorial
                   of temperature advection}
                        {content representation of temperature advection is in
                         the form of a  procedure for using a principle}
                   }
then
        and  {    {display: name/definition of principle temperature advection}
                        {assert goal: display secondary presentation of temperature advection}
                        {display: any prerequisite concept(s) of temperature advection}
                        {display: prerequisite procedure in which
                         principle temperature advection is applied}
                   }
```

Figure 39

Instantiation of Rule ID: 3108a

If
{goal: display secondary presentation of temperature advection}
then
{and/or {dispay: contexual elaboration of temperature advection}
{dispay: mnemonics of temprature advection}
{display: attention focusing devices of temperature advection}
{display: alternate forms of representation of temperature advection}
{assert goal: visualization}
}

Figure 39a: Visualization rule

Rule ID: 3108b

If
{goal: visualization }
then
{and { display: fish tank visualization aid}
{ display: instructions to imagine movement/visualization}
{display: movement of surface line of water}
{display: color blue for CAA, red for WAA}
}

Comment: Implementor to provide animation for movement and color according to suggestions when appropriate.

Figure 40

Instantiation of Rule ID: 3114

if

{goal: display expository generality for expository tutorial of temperature advection}

then {highlight the concepts involved in the principle temperature advection}

DISPLAY:

Name/Definition for Temperature Advection

Temperature advection is the process that transports temperature by the wind. Advection is usually used to describe large scale horizontal movement in the atmosphere. The vertical motions of the atmosphere can be inferred by finding the proper advection patterns. Ultimately, it is the vertical motions in the atmosphere that produce the changes in weather.

Secondary Presentation/Explanation for Temperature Advection

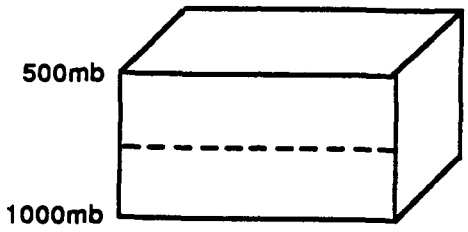
Temperature advection includes cold air advection (CAA) and warm air advection (WAA).
CAA is a good indicator of downward vertical motion, while WAA is a good indicator of upward vertical motion.
CAA is occuring when the value of the temperature, on the thickness chart, is rising with the flow of the wind. WAA occurs when the values of the temperature, on the thickness chart, is sinking with the flow of the wind.

Visualization Aid

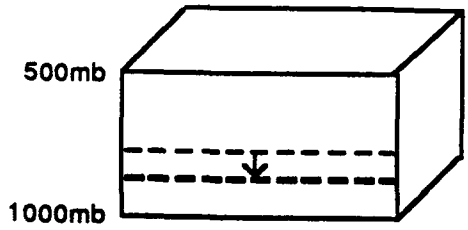
Figure 40a1 is a fish tank with a certain water surface. Imagine that when CAA occurs it is as if the surface of the water will sink since there is pressure and the water becomes more dense (see figure 40a2). The opposite occurs with WAA. It is as if the water become less dense, the surface level will rise (see figure 40a3).

Secondary Presentation/Prerequisite Concept of Temperature Advection

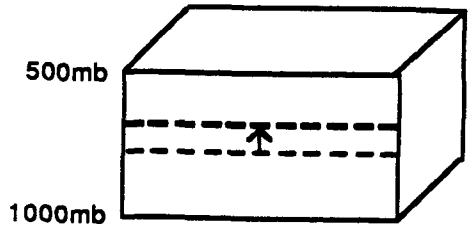
In order to determine temperature advection an advection box needs to be identified on a thickness chart. An advection box is formed when thickness lines and isobars intersect to form a box. Imagine a grid of solid lines and dashed lines and the box that is formed when they intersect.
(Comment: display advection box on screen)
Then, the wind direction needs to be determined. A good rule for that is: *look at the isobars, when the low pressure is at your left, the wind is at your back.*. Try to imagine the direction of the wind when the low pressure is at your left. Then turn around and imagine the direction of the wind now.
(Comment: display graphics of wind direction)
After determining the wind direction, temperature advection can be determine by identifying whether the tempreature is dropping or rising with the wind flow.



(1)



(2)



(3)

Figure 40a. Fish tank with water surface.

Figure 41

Instantiation of Rule ID 3114a

```
If
      and  {  {goal: display expository instance for expository tutorial of temperature advection}
              {content representation of temperature advection is in the form of a
               procedure for using a principle}
           }
then
      and  {  {display: name of principle temperature advection}
              {display: an example where principle temperature advection is applied
               to a specific situation}
              {assert goal: visualization}
           }
```

Figure 41a: Visualization rule

Rule ID: 3108b

If
{goal: visualization }
then
{and { display: WAA chart}
{ display: instructions to imagine movement/visualization}
{display: movement animation of arrow}
{display: color of arrow- red}
}

Comment: Implementor to provide animation for movement and color : since WAA, color red, display movement of arrow of wind direction plus warm air going upward (3D).

DISPLAY:

An Example of temperature advection:

The following is an example of Warm Air Advection (WAA).

(insert figure 41bI)

An advection box is formed by the intersection of the solid and dashed lines. Looking at the values of the isobars, the lower value is 5460. When the lower pressure is at your left the wind is at your back. Therefore, the direction of the wind is from left to right. Imagine the wind flow from left to right and the upward motion of WAA.

(insert figure 41bII)

Looking at the temperature values, they are dropping with the flow of the wind. Therefore the temperature advection is : WAA.

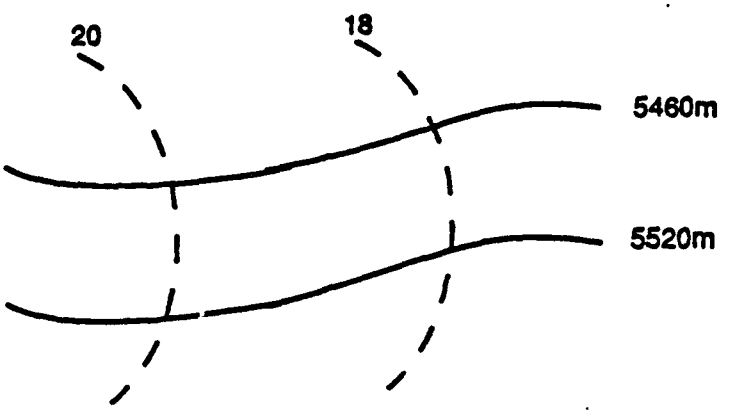
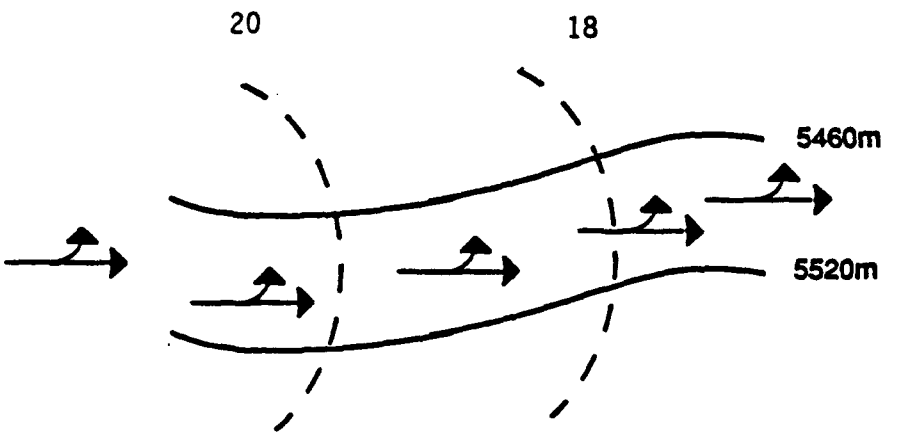


Figure 41bI. Advection box.



WAA

Figure 41bII. Warm air advection visual example.

Figure 42

Instantiation of Rule ID: 3114b

If

{and { goal: display expository instance for expository tutorial of temperature advection}
{principle temperature advection will be applied to a variety of situations}
{an instance of principle temperature advection is already presented}
}

then

{and {display: the next instance where principle temperature advection is applied
To a different situation than the ones already presented}
{assert goal: visualization}
}

Figure 42a: Visualization rule

Rule ID: 3108b

If
{goal: visualization }
then
{and { display: CAA chart}
{ display: instructions to imagine movement/visualization}
{display: movement animation of arrow}
{display: color of arrow- blue}
}

Comment: Implementor to provide animation for movement and color: CAA therefore color blue, animation of wind blow plus cold air going down (3D)

DISPLAY:

The following is an example of Cold Air Advection (CAA):

(insert figure 42bI)

Since the same isobars are used, the wind again will be going from left to right. But, in this example the temperature is rising with the flow of the wind. Therefore, this is an example of CAA. Imagine the flow of the wind and the downward motion of CAA.

(insert figure 42bII)

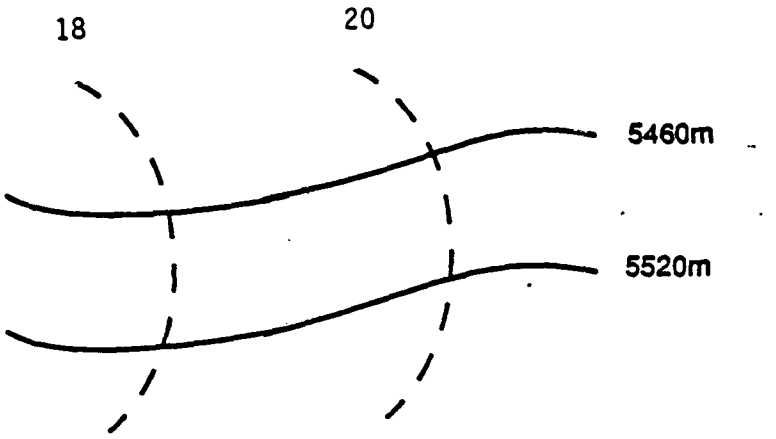


Figure 42bI. Advection box.

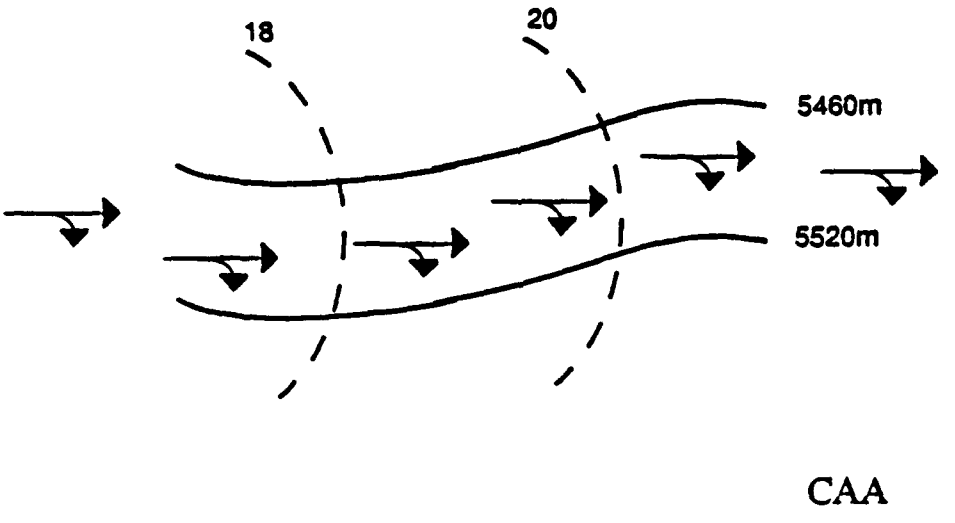


Figure 42bII. Cold air advection visual example.

Figure 43

Instantiation of Rule ID: 3114c

If
and { {goal: display inquisitory instance for expository tutorial of temperature advection}
{content representation of temperature advection is in the form of a procedure for using a principle}
then
{assert goal: remediation mode}

INSTANTIATION OF REMEDIATION RULES

Figure 44 Display Easier Instance Rule

Instantiation of Rule ID: 3419

if
and { {goal: remediation mode}
{goal: display Inquisitory Instance of temperature advection}
{it is the first time the goal is set for the current content}
}
then
{display: an instance in the first rational set with fewest number of relevant attributes}

DISPLAY:

Please indicate (a) upward (b) left to right (c) downward (d) right to left

Temperature advection includes warm air advection (WAA) and cold air advection (CAA).
WAA is a good indicator of _____ motion

Figure 45

Instantiation of Rule ID: 3420

If

and { {goal: display inquisitory instance of temperature advection}
{the learner answered the current instance correctly}
{at the same dificulty level, instances in some rational set have not been presented or have not been answered correctly}
}

then

{display: a different instance in the same rational set}

DISPLAY:

Please indicate (a) upward (b) left to right (c) downward (d) right to left

Temperature advection includes warm air advection (WAA) and cold air advection (CAA).
CAA is a good indicator of _____ motion

Figure 46 Optional Instance Presentation

Instantiation of Rule ID: 3421

if

and { {goal: display Inquisitory Instance of temperature advection}
{the learner answers the instance correctly}
{the learner answers all the instances at the same difficulty level correctly}
}

then

{display: an instance from a rational set different from the current one at a higher difficulty level}

DISPLAY:

The following is an example of :

(a) WAA
(b) PVA
(c) NVA
(d) CAA

(Insert Figure 46a)

CORRECT LEARNER RESPONSE: (a) WAA

Figure 46a

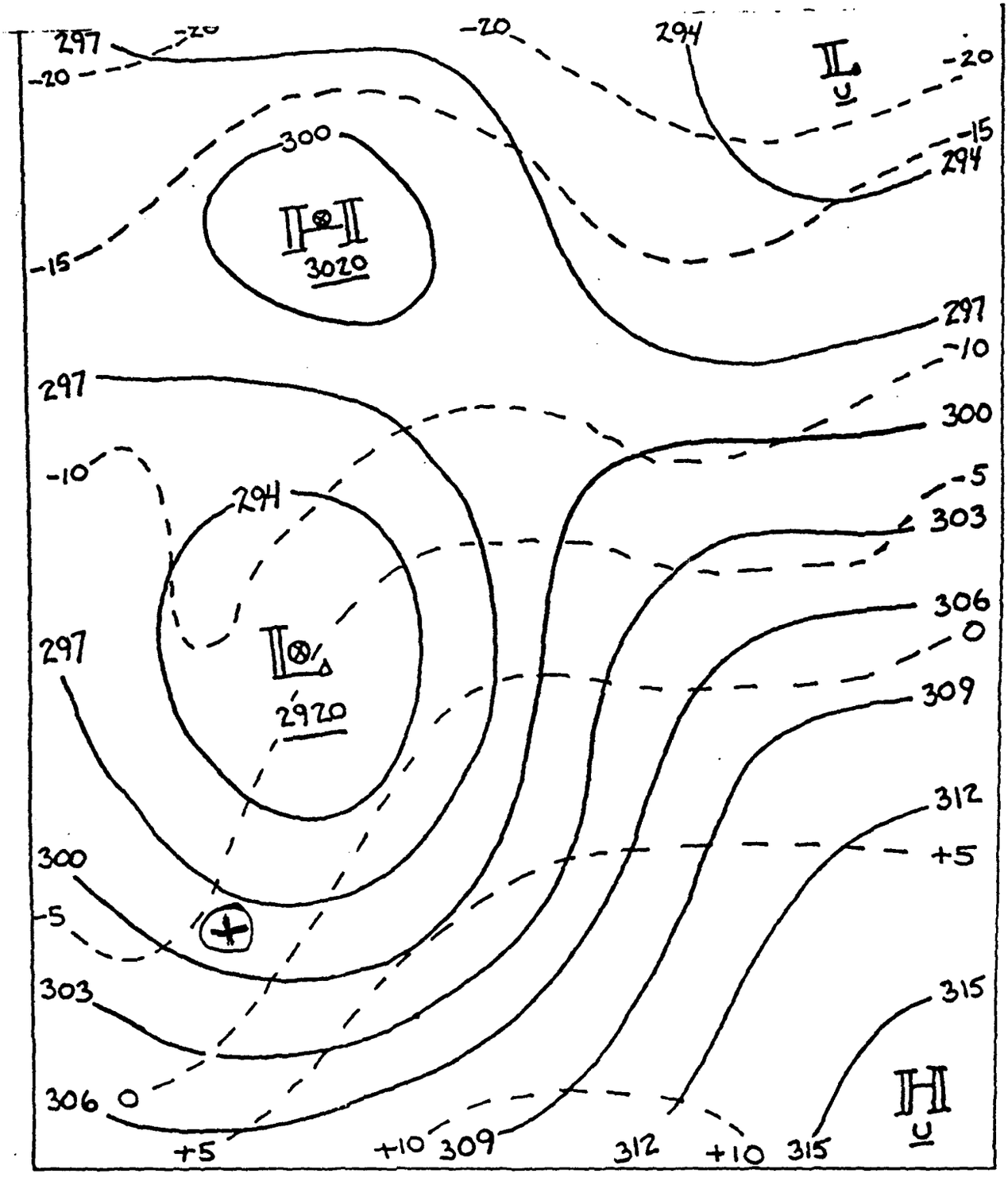

297
-20
-20
-20
294
L
U
-20
-15
294
300
P
3020
-15
297
-10
297
300
-10
294
-5
303
306
297
L
2920
0
309
312
300
+5
-5
303
315
306
0
H
U
+5
+10
309
312
+10
315

Figure 47 Switch from Inquisitory to Expository Instance

Instantiation of Rule ID: 3422

if

{and {goal: display Inquisitory Instance of temperature advection}
{the learner answers the instance incorrectly}
}

then

{and {display: an instance in the same rational set in Expository mode}
{assert goal: visualization}
}

Figure 47a: Visualization rule

Rule ID: 3108b

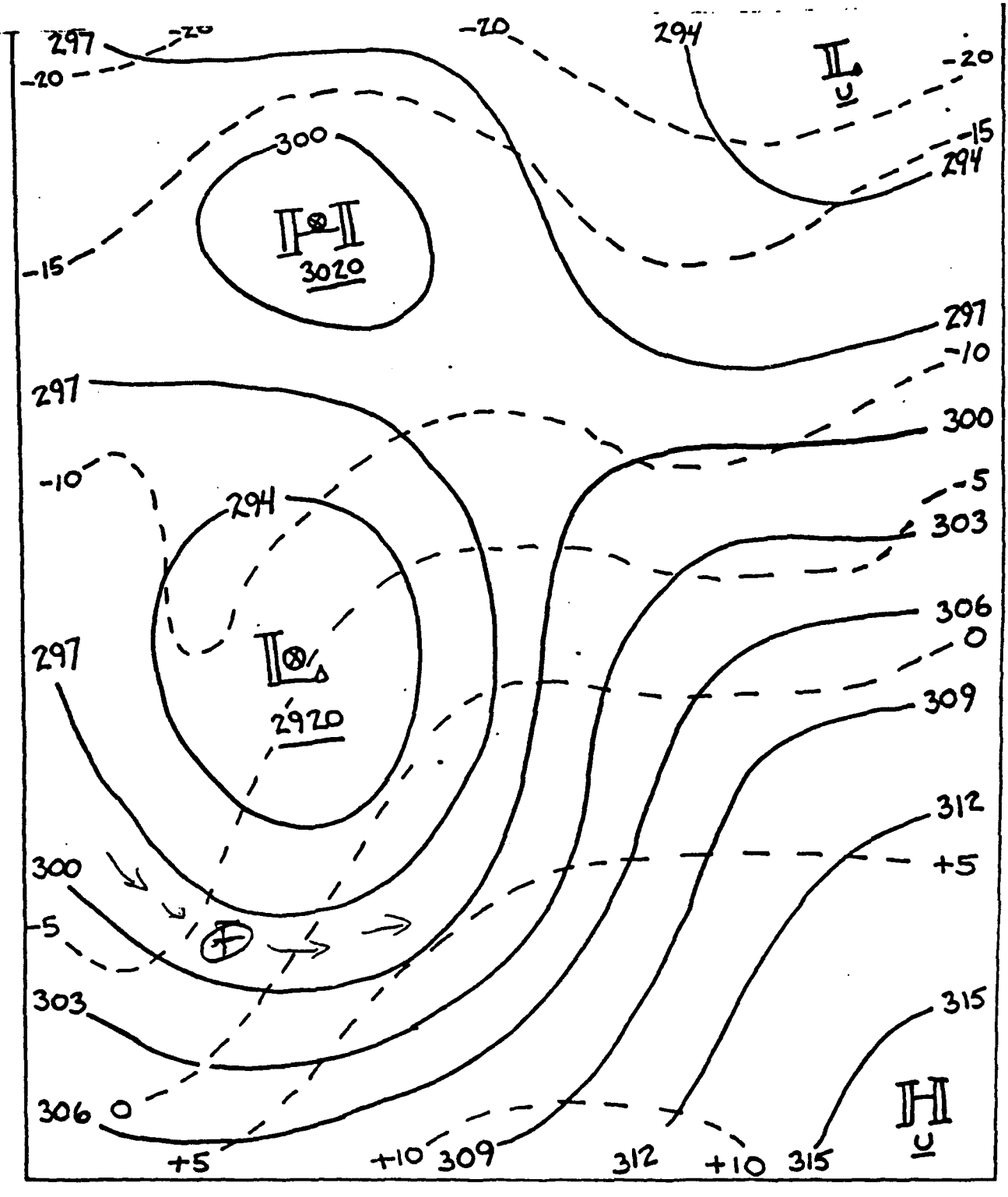
If
{goal: visualization }
then
{and { display: CAA chart}
{ display: instructions to imagine movement/visualization}
{display: movement animation of arrow}
{display: color of arrow- blue}
}

Comment: Implementor to provide animation for movement and color : blue since CAA, animation of wind direction plus air going downward.

DISPLAY:

Look at the chart provided in the question (figure 46a).
WAA occurs when the temperature is dropping with the flow of the wind. CAA is occuring when the temperature is rising with the flow of the wind.
In the previous example the temperature rose with the direction of the wind therefore it was an example of CAA rather than WAA. Imagine the direction of the wind and the motion of the air in CAA. (insert figure 47b).

figure 47b



CAA

Figure 48 Instances to Predict Mastery

Instantiation of Rule ID: 3425

```
if
      and  {     {goal: display Inquisitory Instance of temperature advection}
                       {the number of instances that is already presented is larger than 4}
                       {the learner's score is larger than the criterion}
                 }
then
      and  {     {the learner reached mastery level}
                       {instruction on the set is completed}
                 }
```

USE - PROCEDURE INSTATIATIONS

Figure 49

Instantiation of Rule ID: 3114d

```
If
      {goal: teach Use Procedure wind direction}
then
      and { { assert goal: display expository generality of procedure wind direction}
            { assert goal: display expository instance of procedure wind direction}
            { assert goal: display inquisitory instance of procedure wind direction}
            }
```

Figure 50

Instantiation of Rule ID: 3114e

If

and { { goal: display expository generality of procedure wind direction}
{ content representation of wind direction is in the form of a procedure}

then

and { { display: name/goal of procedure wind direction}
{ display: steps of procedure wind direction}
{ display: order of procedure wind direction}
{ display: decision/branch process of procedure wind direction}
}

DISPLAY:

The following is the procedure for finding the wind direction given a thickness chart:

The steps should be followed in the order shown below:

1. Find an advection box (an advection box is formed when thickness lines and isobars intersect to form a box).

2. Look at the values of the isobars and determine the smaller number.

3. When the lower pressure (smaller value of isobar line) is at your left, the wind is at your back.

Figure 51

Instantiation of Rule ID: 3114f

If
{goal: display expository instance of procedure wind direction}
then
and { {display: name/goal of procedure wind direction}
{display: materials of procedure wind direction}
{display: a demonstration of the execution of procedure wind direction}
{display: the representation of procedure wind direction}
}

DISPLAY:

An example of finding the wind direction given a thickness chart.
Looking at the following thickness chart:

(Insert Figure 51a.)

1. The advection box is the box formed by the intersection of the dashed and solid lines.
2. Looking at the isobars, 5460 is the smaller value.
3. When the 5460m isobar is at your left, the wind is at your back i.e. the wind direction is from left to right.

Figure 52

Instantiation of Rule ID: 3114g

If
{goal: display inquisitory instance of procedure wind direction}
then
{assert goal: remediation mode}

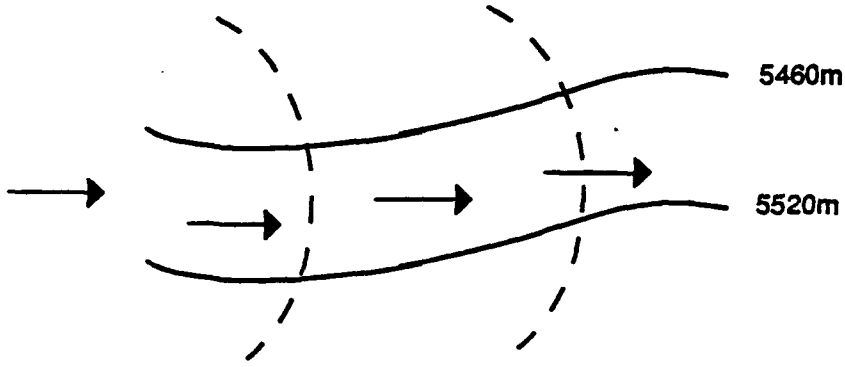


Figure 51a. Wind direction.

Figure 53 Display Easier Instance Rule
Instantiation of Rule ID: 3419

if
and { {goal: remediation mode}
{goal: display Inquisitory Instance of wind direction}
{it is the first time the goal is set for the current content}
}
then
{display: an instance in the first rational set with fewest number of relevant attributes}

DISPLAY:

Indicate the correct order for determining the direction of the wind on a thickness chart:

1. find lower pressure value
2. find advection box
3. determine wind direction by rule

(a) 1,2,3 (c) 2,1,3
(b) 3,2,1 (d) 2,3,1

CORRECT ANSWER: c.

Figure 54
Instantiation of Rule ID: 3420

If
and { {goal: display inquisitory instance of wind direction}
{the learner answered the current instance correctly}
{at the same dificulty level, instances in some rational set have not been presented or have not been answered correctly}
}
then
{display: a different instance in the same rational set}

DISPLAY:

Determine the wind direction in the following chart:

Please indicate: (a) west (b) east (c) south (d) north

(insert figure 54a)

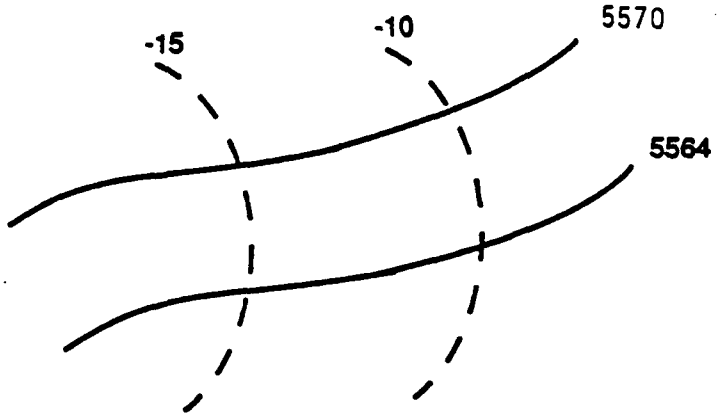


Figure 54a. Wind direction chart

Figure 55 Optional Instance Presentation

Instantiation of Rule ID: 3421

if

and { {goal: display Inquisitory Instance of wind direction}
{the learner answers the instance correctly}
{the learner answers all the instances at the same difficulty level correctly}
}

then

{display: an instance from a rational set different from the current one at a higher difficulty level}

DISPLAY:

Indicate the direction of the wind in the following chart.

Please indicate (a) west (b) north (c) east (d) south.

(insert figure 55a)

CORRECT RESPONSE: a (i.e. west)

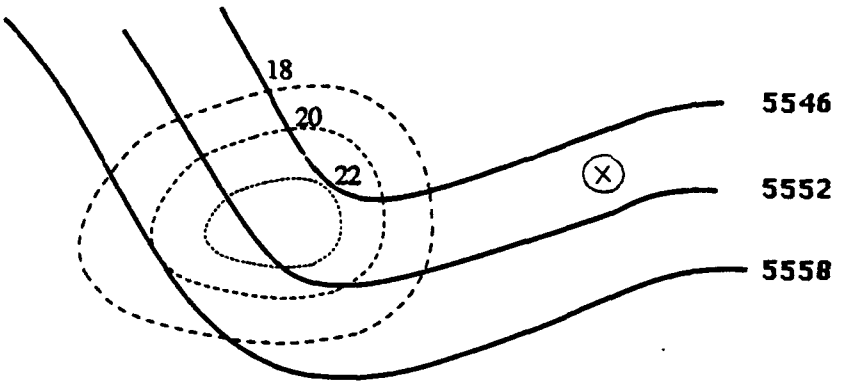


Figure 55a. Wind direction chart.

Figure 56 Switch from Inquisitory to Expository Instance

Instantiation of Rule ID: 3422

if
{and {goal: display Inquisitory Instance of wind direction}
{the learner answers the instance incorrectly}
}

then
{and {display: an instance in the same rational set in Expository mode}
{assert goal: visualization}
}

Figure 56a: Visualization rule

Rule ID: 3108b

If
{goal: visualization }
then
{and { display: thickness chart}
{ display: instructions to imagine movement/visualization}
{display: movement animation of arrow}
{display: color of arrow- black}
}

Comment: Implementor to provide animation for movement and color according to suggestions when appropriate.

DISPLAY:

Look at figure 55a and imagine the direction of the wind.
The wind is blowing east. When the lower pressure is at your left, the wind is at your back.

(insert figure 56b)

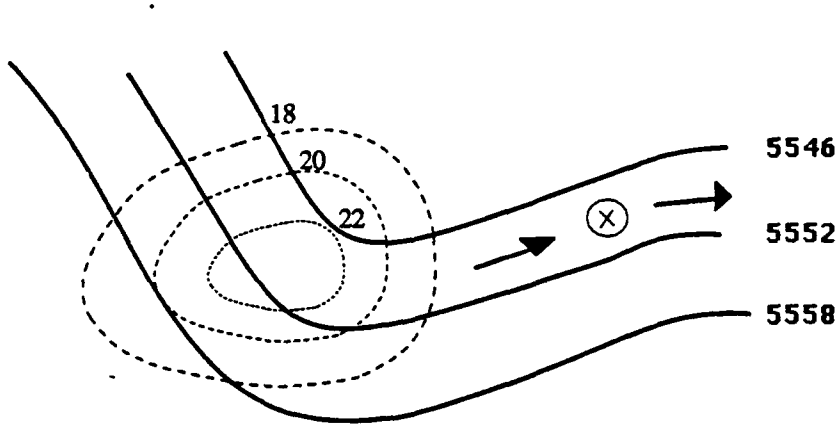


Figure 56b. Wind direction chart.

Figure 57 Instances to Predict Mastery

Instantiation of Rule ID: 3425

if
and { {goal: display Inquisitory Instance of wind direction}
{the number of instances that is already presented is larger than 4}
{the learner's score is larger than the criterion}
}

then
and { {the learner reached mastery level}
{instruction on the set is completed}
}

INSTRUCTIONAL GOAL: USE-CONCEPT + REMEDIATION USE CONCEPT

Figure 58

Instantiation of Rule ID: 3411

if {goal: Use-Concept Thickness chart}

then
and { {assert goal: display Expository Generality of Thickness chart}
{assert goal: display Expository Instance of Thickness chart}
{assert goal: display Inquisitory Instance of Thickness chart}
}

Figure 59

Instantiation of Rule ID: 3412a

if {goal: display Expository Generality of Thickness chart}

then
and { {display: name of Thickness chart}
{display: superordinate concepts of Thickness chart}
{display: relevant attributes of Thickness chart}
{display: best example of Thickness chart}
}

DISPLAY:

THICKNESS CHART

Thickness is the vertical distance between two constant pressure surfaces.
Thickness charts can be constructed between any two constant pressure surfaces.
The utilities of a thickness chart is to evaluate temperature advection, locate frontal positions, locate the approximate position of the polar front jet stream, and delineate between frozen and unfrozen precipitation.
An example is: 1000-500mb thickness chart. This is the most common thickness chart in use for local weather stations. It provides an accepted representation of overall atmospheric features.

Figure 60

Instantiation of Rule ID: 3416

if {goal: display Expository Instance of Thickness chart}

then {display: example with a matched non-example}

DISPLAY:

Other examples of thickness charts (besides the 1000-500mb chart) are:

1000-850mb thickness chart: provides an accurate means of identifying the position of the arctic front (arctic air masses which have moved out of their source region are shallow layers of very cold air), cold core hights, thermal lows, or any low level thermal feature.

850-500mb thickness chart: provides a more accurate representation than the 1000-500mb thickness chart in mountain regions where the surface elevation is near or above 850mb. This chart helps identify fromts in the mountains or over large bodies of water which appear to "wash out" on a 1000-500mb chart.

Figure 61

Instantiation of Rule ID: 3416A

if {goal: display Inquisitory Instance of Thickness chart}

then {assert goal: remediation mode}

Figure 62

Instantiation of Rule ID: 3419

if

and { {goal: remediation mode}
{goal: display Inquisitory Instance of thickness chart}
{it is the first time the goal is set for the current concept}
}

then {display: the instance in a rational set with
fewest number of relevant attributes}

DISPLAY:

What is the most common thickness chart in use at local weather stations?

a. 1000-500mb
b. 1000-850mb
c. 850-500mb
d. 250-500mb

CORRECT RESPONSE: a. 1000-500mb thickness chart.

Figure 63

Instantiation of Rule ID: 3420

if

and { {goal: display Inquisitory Instance of Thickness chart}
{the learner answers the current instance correctly}
{at the same difficulty level, instances in some rational set
have not been presented or have not been answered correctly}
}

then {display: an instance from a rational set
different from the current one}

DISPLAY:
Why is the 1000-500mb thickness chart the most commonly used?
a. provides an accurate representation of overall atmospheric features
b. provides an accurate representation of mountain regions
c. provides acceptable representation of overall atmospheric features
d. provides an acceptable representation of mountain regions.

CORRECT RESPONSE: c.

Figure 64

Instantiation of Rule ID: 3421

if

and { {goal: display Inquisitory Instance of Thickness chart}
{the learner answers the instance correctly}
{the learner answers all the instances at the same difficulty level correctly}
}

the

{display: an instance from a rational set different from the current one at a higher difficulty level}

DISPLAY:

The 850-500mb thickness chart is mainly used for the following purpose:

a. identify fronts in mountains
b. identify the position of the arctic front
c. provides overall representation of atmosphere
d. identify fronts in the ocean

CORRECT RESPONSE: b. identify the position of the arctic front

Figure 65

Instantiation of Rule ID: 3422

if
and { {goal: display Inquisitory Instance of Thickness chart}
{the learner answers the instance incorrectly}
}

then {assert goal: display an instance in the same rational set in Expository mode}

DISPLAY:

The 850-500mb thickness chart provides a more accurate representation of the mountain areas where the surface elevation is near or above 850mb. Therefore, this chart is most commonly used for identifying fronts in the mountains. The 1000-850mb thickness chart is used to identify the position of the arctic front.

Figure 66

Instantiation of Rule ID: 3425

if
and { {goal: display Inquisitory Instance of Thickness chart}
{the number of instances that is already presented is larger than 4}
{the learner's score is larger than the criterion}
}
then
and { {the learner reached mastery level}
{instruction on the set of concepts is completed}
}

INSTRUCTIONAL GOAL: Remember-Fact

Figure 67

Instantiation of Rule ID: 3400

if {goal: teach Remember-Fact: Isotherms}

then
and { {assert goal: display Expository Instance of Isotherms}
{assert goal: display Inquisitory Instance of Isotherms}
}

Figure 68

Instantiation of Rule ID: 3402

if
{goal: display Expository Instance Isotherms}
then
{display: new facts and relate them to the prior knowledge of the learner}

DISPLAY:

Isotherms are thickness lines in a thickness chart.
Isotherms are represented by dashed lines.

Figure 69

Instantiation of Rule ID: 3406

if
{goal: display Inquisitory Instance of Isotherms}
then
{assert goal: remediation mode}

REMEDIATION RULES

Figure 70 Display Easier Instance Rule

Instantiation of Rule ID: 3419

if
and { {goal: remediation mode}
{goal: display Inquisitory Instance of Isotherms}
{it is the first time the goal is set for the current content}
}
then
{display: an instance in the first rational set with fewest number of relevant attributes}

DISPLAY:

How are thickness lines on a thickness chart called?
a. isobars
b. isotherms
c. isomores
d isoplats

CORRECT ANSWER: b. isotherms

Figure 71

Instantiation of Rule ID: 3420

If

and { {goal: display inquisitory instance of Isotherms}
{the learner answered the current instance correctly}
{at the same dificulty level, instances in some rational set have not been presented or have not been answered correctly}
}

then

{display: a different instance in the same rational set}

DISPLAY:

What are Isotherms?

(a) pressure lines on a pressure chart
(b) presuure lines on a thickness chart
(c) thickness lines on a pressure chart
(d) thickness lines on a thickness chart

CORRECT ANSWER: (d) thickness lines on a thickness chart

Figure 72 Optional Instance Presentation

Instantiation of Rule ID: 3421

if

and { {goal: display Inquisitory Instance of Isotherms}
{the learner answers the instance correctly}
{the learner answers all the instances at the same difficulty level correctly}
}

then

{display: an instance from a rational set different from the current one at a higher difficulty level}

DISPLAY:

Isotherms are represented on a thickness chart as:

a. solid lines
b. dashed lines
c. solid or dashed lines
d. solid and dashed lines

CORRECT RESPONSE: a.

Figure 73 Switch from Inquisitory to Expository Instance

Instantiation of Rule ID: 3422

if
and { {goal: display Inquisitory Instance of Isotherms}
{the learner answers the instance incorrectly}
}

then {display: an instance in the same rational set in Expository mode}

DISPLAY:

Isotherms are represented by dashed lines on a thickness chart, not by solid lines.

Figure 74 Instances to Predict Mastery

Instantiation of Rule ID: 3425

if
and { {goal: display Inquisitory Instance of Isotherms}
{the number of instances that is already presented is larger than 4}
{the learner's score is larger than the criterion}
}

then
and { {the learner reached mastery level}
{instruction on the set is completed}
}